Center for Independent Experts (CIE) Independent Peer Review Report of the Underwater Calculator and Associated Documentation

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Executive Summary

The author of this report was asked to review an excel spreadsheet known as the "underwater calculator" (UWC, referred to in the body of this report as "UWC 2" because it is version 2 of the calculator) for estimating the strength of the underwater sound field in the vicinity of an explosion in the seabed, and associated documentation. Clear terminology is essential for effective communication and this review focuses on the terminology used. The UWC and the associated final report were reviewed.

The UWC was developed by identifying and then implementing empirical correlations between acoustic parameters (metrics) characterising the field strength and input parameters such as the explosive charge mass and burial depth. The metrics are then compared with risk thresholds in the form of criteria for hearing threshold shift, disturbance and injury. The findings of this reviewer are

- the correlation method used is the best available science for this difficult problem; it is applicable within validity limits that need to be specified;
- the meaning of the UWC outputs is unclear because of unclear terminology;
- the meaning of the criteria is unclear because of unclear terminology;
- there is a risk that the UWC outputs are not directly compatible with the criteria, especially with regard to uncertainties in the EFD integration window and the definition of the pressure impulse.

The recommendations of this reviewer are:

- specify validity limits for the UWC;
- clarify terminology of UWC, especially with regard to EFD integration window and pressure impulse definition;
- clarify terminology of criteria, especially with regard to pressure impulse;
- adopt international standard terminology and SI units for scientific work; where it is necessary to convert to units outside the SI, adopt a suitable national or international standard for this conversion.

Preface

I was invited to review a set of reports describing an underwater calculator whose purpose is to predict acoustic metrics associated with the impact of explosions, and associated impact ranges. Much of my review effort has gone into understanding the quantities calculated by the underwater calculator and comparing these quantities with the requirements of the acoustic criteria used to assess impact. Much of this effort, in turn, has gone into understanding the terminology used by the underwater calculator and the criteria. This review serves to document my understanding of the terminology used; I hope it helps others.

1. Introduction

The review of metrics and terminology took a substantial proportion of the time available, such that only the calculator itself and the main report (Dzwilewski, 2014) were reviewed. There was insufficient time left to review the other reports.

Two different versions of the underwater calculator are described in the reports made available for review. The present report reviews the Excel spreadsheet 'UWC Version 2.0 - 3 Jan 2014.xlsx' (henceforth abbreviated 'UWC 2') and the associated report (Dzwilewski , 2014). Specifically, it contains the following sections:

- General remarks on terminology
- Review of the Underwater Calculator (UWC 2)
- Review of the UWC 2 report (Dzwilewski, 2014)
- Conclusions and recommendations
- Terms of Reference
- Acknowledgements
- References
- Appendix 1: Bibliography
- Appendix 2: Statement of Work
- Appendix 3: cited correspondence with Dr. P. Dzwilewski

2. General remarks on terminology

The terminology used in the reviewed report (Dzwilewski, 2014) appears to follow closely that of Cole (1948). The terminology of Cole 1948 is dated and not consistent with modern national (ANSI, 2013) or international (ISO 2016) standards, nor with Morfey's Dictionary of Acoustics (Morfey, 2000). The author of this review has done his best to document the terminology used by the underwater calculator and accompanying report.

As an example, consider the meaning of "energy flux density" (EFD):

- Cole (1948) uses the term EFD as a synonym of time-integrated sound intensity. If this reviewer has understood correctly, the underwater calculator defines it in a slightly different way, namely as the ratio of the sound exposure to the characteristic acoustic impedance of seawater. The two quantities are the same for low amplitude sound in the far field. In the near field and for high amplitude sound they differ.
- EFD is defined by ANSI (ANSI 1994, 2013) as the (time-averaged) sound intensity, in conflict with Cole's definition as the *integral* of this quantity.
- the EFD integration time is unspecified.

A clear report requires a clear language and a clear terminology, and the absence of a list of terms used with their definitions provided a challenge to this reviewer. He has responded to this challenge by providing a detailed description of the terminology used to his best understanding at the time of writing. Many of the problems originate neither from the calculator or accompanying report, but from ambiguities in the criteria the calculator seeks to implement, and in the language used to describe those criteria.

3. Review of UWC 2

In this section the Excel spreadsheet 'UWC Version 2.0 - 3 Jan 2014.xlsx' (abbreviated UWC 2), is reviewed. The spreadsheet carries out two types of calculation. The first type is the calculation of acoustic field metrics related to impact, such as peak sound pressure; the second type is the calculation of a distance within which a specified impact is considered to occur.

3.1. Forward calculation

Three quantities are calculated (Figure 1), these are "Peak Pressure", "Peak Impulse" and "Peak EFD", where "EFD" is an abbreviation for energy flux density. The definitions of these three terms, as understood by this reviewer are shown in Table 1.

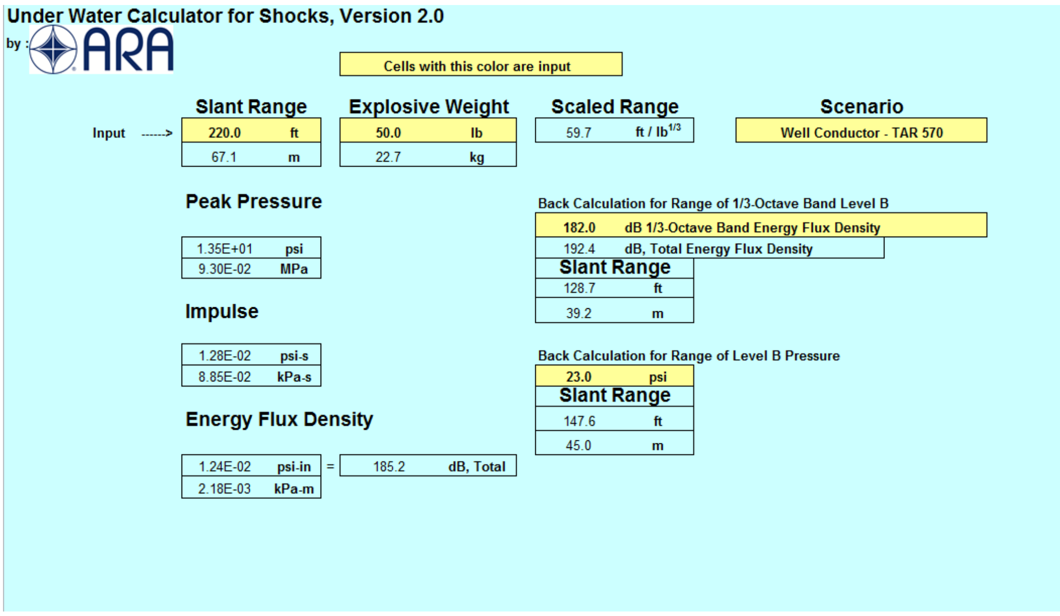

Figure 1 – Screen showing UWC 2 forward calculation results for 50 lb charge at a distance of 220 ft (well conductor scenario). Also shown are the back-calculation of the impact distances for a peak sound pressure of 23 lbf/in^2 and one-third octave band sound exposure level of 182 dB re 1 mPa^2 s.

Table 1 – Definitions of calculator output, as understood by this reviewer at the time of writing

term (and synonyms) used by UWC 2 and Dzwilewski (2014)	symbol	definition	notes
Peak Pressure Pm	$p_{\mathrm{pk,c}}$	$p_{\mathrm{pk,c}} \equiv \max p(t)$, where $p(t)$ is the sound pressure.	The term "peak pressure" is a misnomer for this quantity because it is not equal to the peak pressure. A more appropriate term, used throughout this report, is "peak overpressure".
Peak Impulse Impulse	$I_{\mathrm{pk.c}}$	$I_{\mathrm{pk.c}} \equiv \max I(\tau)$, where $I(\tau) \equiv \int_0^\tau p(t)\,\mathrm{d}t$	Strictly speaking this quantity is the peak *positive* impulse, because negative sound pressures are excluded from the integral. The term "peak positive impulse" is therefore used in this report.
Peak EFD Energy Flux Density EFD	J_{tot}	$J_{\mathrm{tot}} \equiv \lim_{\tau\to\infty} J(\tau)$, where $J(\tau) \equiv \frac{1}{\rho_0 c_0} \int_0^\tau p^2(t)\,\mathrm{d}t$.	This definition is from Dzwilewski & Fenton (2003). It represents a departure from that of Cole (1948), which defines as time-integrated sound intensity. The two quantities are identical in the far field and when amplitudes are sufficiently small for the assumptions of linear acoustics to hold. The integration is assumed to take place over the entire pulse. The term "energy flux density" (abbreviated EFD) is used for this term throughout this report.

The calculator works in customary inch-pound units (IEEE, 2004), henceforth abbreviated "CIP units". Conversions to SI units are provided in Table 2. The equations below are expressed in CIP units for consistency with the calculator. The UWC 2 calculator engine is implemented in CIP units, with conversions provided to SI units for some outputs.

Table 2 – Conversions between customary inch-pound units and SI units (source: IEEE, 2004)

customary inch-pound unit	conversion to SI unit	notes
pound force, symbol lbf	4.4482 N	unit of force approximate conversion
inch, symbol in	2.54 cm	unit of distance definition (exact)
foot, symbol ft	0.3048 m	unit of distance definition (exact)
pound (avoirdupois), symbol lb	0.453 592 37 kg	unit of mass definition (exact)
pound force per square inch, symbol $\mathrm{lbf/in^2}$	$\frac{4.4482\ \mathrm{N}}{(2.54\ \mathrm{cm})^2} \approx 6895\ \mathrm{Pa}$	unit of pressure, abbreviated 'psi'
pound force second per square inch, symbol $(\mathrm{lbf/in^2})\ \mathrm{s}$ or $\mathrm{lbf\ s/in^2}$	$\frac{4.4482\ \mathrm{N\ s}}{(2.54\ \mathrm{cm})^2}$ $\approx 6895\ \mathrm{Pa\ s}$	unit of impulse derived
pound force inch per square inch, symbol $(\mathrm{lbf/in^2})\ \mathrm{in}$ or $\mathrm{lbf\ in/in^2}$	$\frac{4.4482\ \mathrm{N}}{2.54\ \mathrm{cm}}$ $\approx 214.5\ \mathrm{Pa\ m}$	unit of energy flux density derived 1 Pa m = 1 J/m^2

The peak overpressure at distance R_{ft} feet is calculated by UWC 2 as

$$p_{\mathrm{pk,c}} = K_p \left(\frac{W_{\mathrm{lb}}^{\frac{1}{3}}}{R_{\mathrm{ft}}} \right)^{\alpha_p} \quad \mathrm{lbf/in^2},$$

where W_{lb} is the charge mass expressed in pounds, and K_p, α_p are scenario-dependent constants. Examples are provided below, in Table 3, for selected scenarios. The symbol $\mathrm{lbf/in^2}$ represents the unit pound-force per square inch (abbreviated psi), and is approximately equal to 6895 Pa (see Table 2).

Table 3 – Values of *K* and *α* used by UWC 2 for selected scenarios

	K_p	α_p	K_I	α_I	K_J	α_J
open water	23514	1.14	1.482	0.91	2659	2.04
main pile - TAR 570	41976	1.836	1.622	1.292	3130.7	2.953
well conductor - TAR 570	3221	1.339	1.3536	1.458	1004.6	3.082

Similarly the peak positive impulse and energy flux density are calculated using

$$I_{\mathrm{pk.c}} = W_{\mathrm{lb}}^{\frac{1}{3}} K_I \left(\frac{W_{\mathrm{lb}}^{\frac{1}{3}}}{R_{\mathrm{ft}}} \right)^{\alpha_I} \quad (\mathrm{lbf/in^2\,})\mathrm{s}$$

and

$$J_{\mathrm{tot}} = W_{\mathrm{lb}}^{\frac{1}{3}} K_J \left(\frac{W_{\mathrm{lb}}^{\frac{1}{3}}}{R_{\mathrm{ft}}} \right)^{\alpha_J} \quad (\mathrm{lbf/in^2})\ \mathrm{in}\,.$$

See Table 2 for explanations of the CIP units used in the above equations, and conversions to their SI counterparts. For example, at distance 220 ft from a 50 lb charge mass (well conductor – TAR 570), the above equations give

$$p_{\mathrm{pk,c}} = 13.5\ \mathrm{lbf/in^2}$$

$$I_{\mathrm{pk,c}} = 0.0128\ \mathrm{lbf\ s/in^2}$$

$$J_{\mathrm{tot}} = 0.0124 \frac{\mathrm{lbf}}{\mathrm{in}},$$

consistent with UWC 2 (see Figure 1).

3.2. Back-calculation

In addition to calculate peak overpressure, peak positive impulse and EFD for a specified distance, the calculator provides a calculation of the impact distance for two acoustic criteria: one in terms of peak overpressure; the other in terms of EFD. The implemented criterion for peak overpressure is $p_{\mathrm{pk,c}} > 23\ \mathrm{lbf/in^2}$, for which the impact distance is

$$R_p = W_{\mathrm{lb}}^{\frac{1}{3}} \left(\frac{K_p}{p_{\mathrm{psi}}} \right)^{1/\alpha_p} \ \mathrm{ft},$$

where

$$p_{\mathrm{psi}} = 23.$$

The UWC 2 criterion for EFD is $L_{1/3} > 182\ \mathrm{dB}$, where $L_{1/3}$ is the maximum one-third octave band sound exposure level. The corresponding impact distance is calculated as

$$R_J = \left(\frac{W_{\mathrm{lb}}^{\frac{1+\alpha_J}{3}} K_J}{J_{\mathrm{lbf/in}}} \right)^{\frac{1}{\alpha_E}},$$

where

$$J_{\mathrm{lbf/in}} = \frac{E_0/(\rho_0 c_0)}{\mathrm{lbf/in}} 10^{\frac{L_{\mathrm{tot}}}{10\ \mathrm{dB}}},$$

$$E_0 = 1\ \mu\mathrm{Pa}^2\mathrm{s}$$

$$c_0 = 1500\ \mathrm{m/s}$$

$$\rho_0 = 1025 \frac{\mathrm{kg}}{\mathrm{m}^3}.$$

Here L_{tot} is the total (broadband) sound exposure level.

$$L_{\mathrm{tot}} = 10 \log_{10} \frac{E}{E_0}\ \mathrm{dB},$$

where E is the sound exposure:

$$E = \rho_0 c_0 J.$$

It is converted to the corresponding 1/3 oct band level by an empirical correlation from (Dzwilewski & Fenton, 2003). The result of the correlation (see Figure 2) is

$$L_{\mathrm{tot}} = \frac{L_{1/3} - 21.419\ \mathrm{dB}}{0.8345}.$$

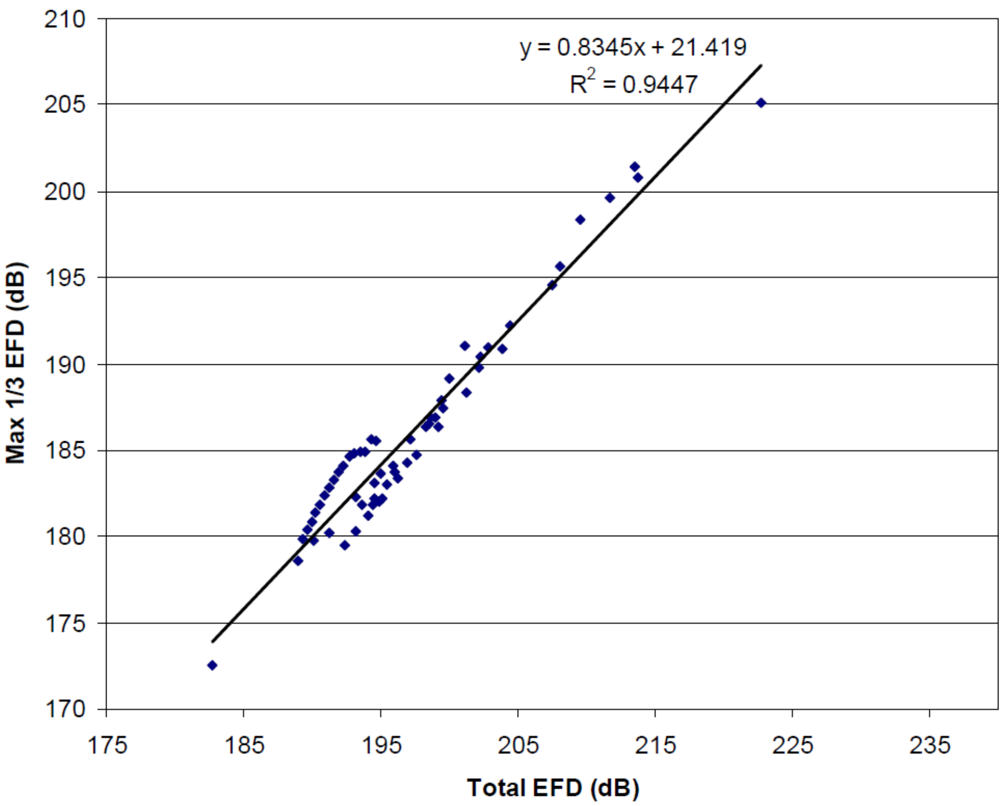

Figure 13. Relationship Between Maximum EFD in any 1/3-Octave Band and Total EFD.

Figure 2 – Correlation between maximum 1/3 octave SEL and broadband SEL, from Dzwilewski & Fenton, 2003.

This correlation seems to provide a reasonable fit to the available measurements, but its use for extrapolation to other circumstances is questionable, as the spectrum in general will depend on charge mass, distance from the explosion and on scenario. However, this reviewer understands that the 1/3 octave criterion is no longer in use by NMFS (personal communication, Scholik-Schomer, 9 August 2014).

Examples of selected impact ranges, calculated using the above equations for R_p and R_J, are shown in Table 4. See also Figure 3.

Table 4 – Table of test values for back-calculation of R_p and R_J.

charge mass	peak overpressure pressure	1/3 oct band SEL	scenario	R_p	R_J
50 lb	$23\ \mathrm{lbf/in^2}$		well conductor – TAR 570	147.64 ft	
50 lb		182 dB	well conductor – TAR 570		128.64 ft

200 lb	23 lbf/in^2		well conductor – TAR 570	234.37 ft	
200 lb		182 dB	well conductor – TAR 570		237.24 ft
50 lb	23 lbf/in^2		open water	1608.1 ft	
50 lb		182 dB	open water		1272.8 ft

Cells with this color are input		
	200.0	lbs, Explosive Weight
	182.0	dB, 1/3-Octave Band Energy Flux Density
	192.4	dB, Total Energy Flux Density
	23.0	Psi

Back Calculation for Range of 1/3-Octave Band Level B

Back Calculation for Range of Level B Pressure

Note: Coefficient and seawater parameters come from the corresponding table on the previous sheet.

Coefficients for Scenarios

	Pm		Impulse		EFD			
Scenario Type	K	a	K	a	K	a	Level B Pressure, ft	Level B EFD, ft
Open Water Exp[1]	23514	1.14	1.482	0.91	2659	2.04	2552.8	2534.47
Main Pile - TAR 570 [2]	41976	1.836	1.622	1.292	3130.7	2.953	349.4	409.87
Well Conductor - TAR 570 [2]	3221	1.339	1.3536	1.458	1004.6	3.082	234.4	237.26
Open Caisson - TAR 570 [2]	4036	1.397	0.82939	1.284	579.4	2.839	236.3	268.34
Main Pile - Connor [3]	75160	1.93	15.35	1.79	11900	3.13	387.1	493.79
Well Conductor (air term) - Connor [3]	49265	1.807	37.41	1.89	52330	3.4	407.7	536.70
Skirt Pile - Connor [3]	70380	2	75.11	2.23	97070	3.82	323.5	383.87
USER								

rho (kg/m^3)	1025	
c (m/s)	1500	**Water Properties**
Z	1537500	

Figure 3 – Screen showing UWC 2 back-calculation results for 200 lb charge. The risk thresholds are 23 lbf/in^2 for peak overpressure and 182 dB re 1 mPa^2 s for 1/3-Octave Band SEL.

4. Review of Dzwilewski 2014

4.1. Report overview

The reviewed report describes the implementation and performance of the calculator UWC 2, based on empirical correlations between charge mass, distance from the explosion and several acoustic metrics. The application is explosive removal of underwater structures (piles). These piles have diameter in the range 36-48 in and wall thickness 1.0-1.5 in.

Results are presented for explosive charge mass in the range 25-145 lb and for detonations at depths between 15-30 ft below the water-mud boundary, expressed as 15-30 “ft BML” where BML is an abbreviation of ”below the mudline”.

The measurements are from Poe et al. (2009).

This reviewer found no clear statement defining the terminology used, which makes the report difficult to follow. The same criticism applies to the acoustic criteria implemented by UWC 2, in that the physical quantities corresponding to the specified thresholds for impact are not defined.

4.2. Selected examples

Some examples of correlations used are shown in Figure 4. In these graphs the straight lines correspond to the equations in Sec 3.1 for peak overpressure, peak positive impulse and EFD. For most cases shown the correlation illustrate a satisfactory fit. As for any empirical correlation, the validity of the resulting data fit is limited by the range of values used to determine the correlation coefficients. Some examples where the empirical correlation works less well are illustrated by Figure 5. These examples are all taken directly from Dzwilewski (2014), so the reader of that report is adequately informed of these departures. Nevertheless, what is missing is a clear description of the limitations in the sense of upper and lower bounds for range, scaled range and charge mass, within which UWC 2 is deemed to be valid.

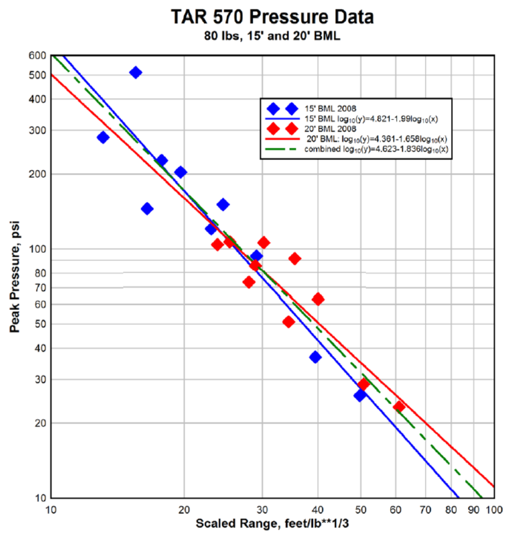

Figure 3. Peak Pressure versus Scaled Range for 80-lb. Main Pile Shots

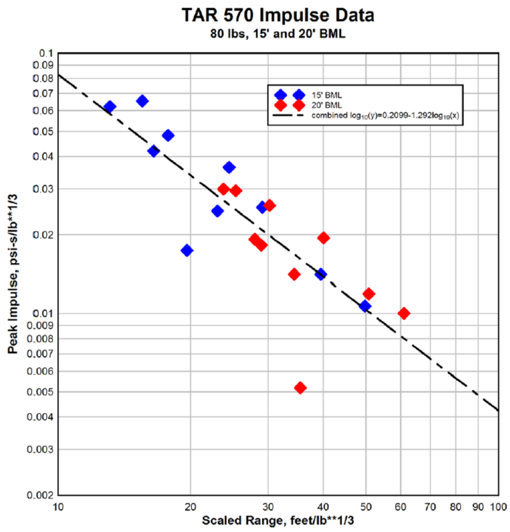

Figure 5. Peak Scaled Impulse versus Scaled Range for 80-lb. Main Pile Shots

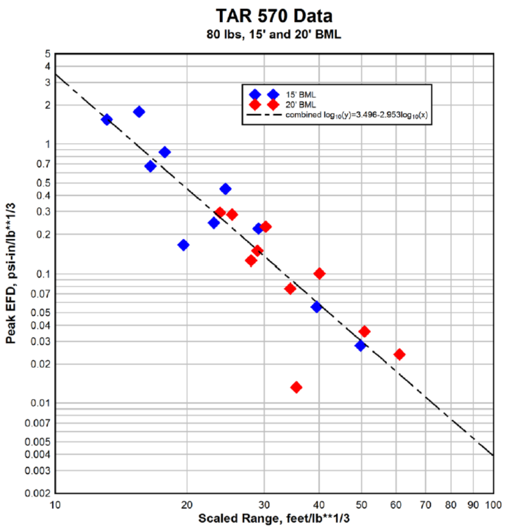

Figure 6. Peak Scaled EFD versus Scaled Range for 80-lb. Main Pile Shots

Figure 4 – Upper left: peak overpressure vs scaled range $R_{\mathrm{ft}}/W_{\mathrm{lb}}^{\frac{1}{3}}$; upper right: Scaled peak positive impulse $I_{\mathrm{pk.c}}/W_{\mathrm{lb}}^{\frac{1}{3}}$ vs scaled range $R_{\mathrm{ft}}/W_{\mathrm{lb}}^{\frac{1}{3}}$; lower left: Scaled EFD $J_{\mathrm{tot}}/W_{\mathrm{lb}}^{\frac{1}{3}}$ vs scaled range $R_{\mathrm{ft}}/W_{\mathrm{lb}}^{\frac{1}{3}}$.

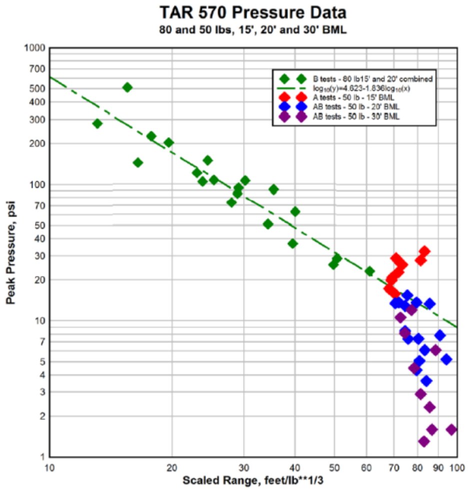

Figure 4. Peak Pressure versus Scaled Range for 50- and 80-lb. Main Pile Shots

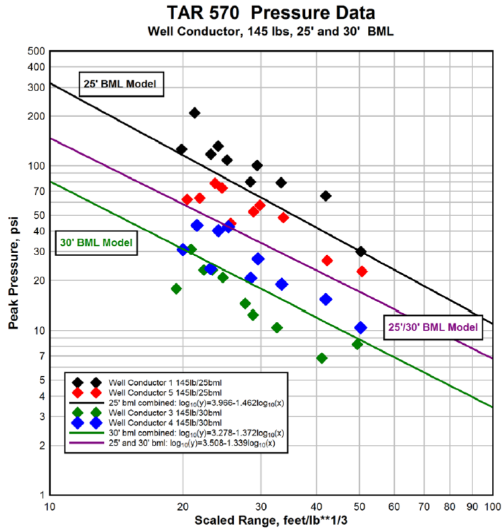

Figure 7. Peak Pressure versus Scaled Range for 145-lb. Well Conductor Shots

Figure 5 – Left: The calculator overestimates peak overpressure for AB tests (50 lb charge, especially 30 ft BML) and underestimates for A tests (50 lb charge, 15 ft BML). Right: The calculator (magenta line) overestimates peak overpressure for well conductor 3 (145 lb charge, 30 ft BML) and underestimates for well conductor 1 (145 lb charge, 25 ft BML).

4.3. Criteria

Relevant acoustic criteria are listed in the report on p30 as Figure 24, reproduced as Figure 6 below.

These criteria specify thresholds of physical quantities. In order to address the question "does UWC 2 calculate appropriate physical quantities?" it is first necessary to know the nature of the physical quantity involve in each of the criteria, but this information is not specified in the criteria listed (see Figure 6). In order to improve his understanding of the criteria, this reviewer entered into discussion with Dr. A. Scholik-Schomer, and his understanding of these criteria after this discussion is described in Table 5.

Criterion	Criterion Definition	Threshold
Level A (mortality)	Onset of severe lung injury (mass of dolphin calf)	31 psi-msec
Level A (injury)	50% animals would experience ear drum rupture	205 dB re: 1 μPa^2-s
Level A (injury)	Onset of slight lung injury (mass of dolphin calf)	13 psi-msec
Level B	TTS and associated behavioral disruption (dual criteria)	12 psi peak (> 2000 lb*) 23 psi peak (< 2000 lb)
Level B	TTS and associated behavioral disruption (dual criteria)	182 dB re: 1 μPa^2-s, 1/3 octave band
Level B	Sub-TTS behavioral disruption (for multiple detonations only)	177 dB re: 1 μPa^2-s, 1/3 octave band

Figure 24. Acoustic Criteria from NMF[5]

Figure 6 – Criteria attributed to NMFS, as listed by Dzwilewski (2014).

Table 5 – Definitions of the quantities used in the NMFS criteria (Figure 6), as understood by this reviewer at the time of writing. ***All statements in this table are tentative and in need of confirmation by the relevant authorities*.**

Criterion Definition (verbatim from Figure **6)**	**quantity (symbol)**	**Criterion as understood by MAA at time of writing**	**notes**
Onset of severe lung injury (mass of dolphin calf)	peak pressure impulse = larger of peak positive impulse and peak negative impulse (I_{pk}): $I_{\mathrm{pk}} = \max(I_{\mathrm{pk,c}}, I_{\mathrm{pk,r}})$ The integration window is that window which maximises the magnitude of the impulse	$I_{\mathrm{pk}} > 31\ (\mathrm{lbf}/\mathrm{in}^2)\ \mathrm{ms}$	This interpretation is contradicted by the definition of "impulse" on p 3.0-46 of (USN, 2012) as the "time integral of the [first and largest pressure peak above static pressure]", which excludes the possibility of rarefactional pressures (negative sound pressure) contributing to the impulse. In addition, in shallow water, and distances exceeding a few water depths, the first peak is usually not also the largest one, making the USN 2012 definition inapplicable in the scenarios of relevance to UWC 2. See also a related statement on p23 of Ainslie (2012, p23). The impulse is calculated for broadband sound pressure (unweighted).
50% animals would experience ear drum rupture	broadband sound exposure level (L_{tot}) The integration window is over the entire pulse	$L_{\mathrm{tot}} > 205$ dB dB re 1 mPa^2 s	The sound exposure is calculated for broadband sound pressure (unweighted).

Onset of slight lung injury (mass of dolphin calf)	peak pressure impulse	$I_{\mathrm{pk}} > 13\ (\mathrm{lbf}/\mathrm{in}^2)\ \mathrm{ms}$	
TTS and associated behavioral disruption (dual criteria)	zero to peak sound pressure, defined as the larger of the peak compressional pressure and peak rarefactional pressure $p_{\mathrm{pk}} = \max(p_{\mathrm{pk,c}}, p_{\mathrm{pk,r}})$	For charge mass less than 2000 lb: $p_{\mathrm{pk}} > 23\ \mathrm{lbf}/\mathrm{in}^2$ For charge mass greater than 2000 lb: $p_{\mathrm{pk}} > 12\ \mathrm{lbf}/\mathrm{in}^2$	broadband (unweighted) sound pressure
TTS and associated behavioral disruption (dual criteria)	one-third octave band sound exposure level ($L_{1/3}$)	$L_{1/3} > 182$ dB re 1 mPa^2 s	The 1/3 oct band is the one that results in the largest value of SEL for frequencies above: 10 Hz for mysticetes; 100 Hz for odontecetes. When in use, this threshold was for unweighted SEL, but it has been superseded by the NOAA 2016 guidance for which SEL thresholds are all weighted.
Sub-TTS behavioral (for multiple detonation s only)	one-third octave band sound exposure level ($L_{1/3}$)	$L_{1/3} > 177$ dB re 1 mPa^2 s	For behaviour the risk threshold is 5 dB down from the TTS threshold – this 5 dB difference still applies, but now for the NOAA 2016 guidance.

The peak sound pressure used in the criteria could be larger than peak overpressure calculated by UWC 2, leading to underestimate of impact range. This effect is unlikely to be large.

The peak pressure impulse used in the criteria could be larger than peak positive impulse calculated by UWC 2, leading to underestimate of impact range.

If the integration window for EFD is less than the entire pulse, the sound exposure used in the criteria could be larger than the EFD calculated by UWC 2, leading to underestimate of impact range.

Consider the risk of underestimating the peak impulse in particular. The perceived risk is a consequence of UWC 2 (to the best of this reviewer’s understanding – see Table 1) neglecting negative sound pressures in its calculation of peak impulse, while the corresponding criteria (again, to the best of this reviewer’s understanding) would require large negative sound pressures to be considered. The blue curve in Figure 7 illustrates this risk because the magnitude of the area in the region of negative sound pressure (38-41 ms) seems from this graph to be greater than the magnitude of the area in the region of positive sound pressure (36-38 ms). One might imagine because the blue curve is weaker than the red or black ones, that it is somehow less important. In fact the magnitude of the impulse in question, depending on precisely how it is calculated, is on the order of a few tens of psi, precisely in the region relevant to injury (for which the stated risk threshold is $13\ (\mathrm{lbf}/\mathrm{in}^2)\ \mathrm{ms}$) and mortality (threshold $31\ (\mathrm{lbf}/\mathrm{in}^2)\ \mathrm{ms}$).

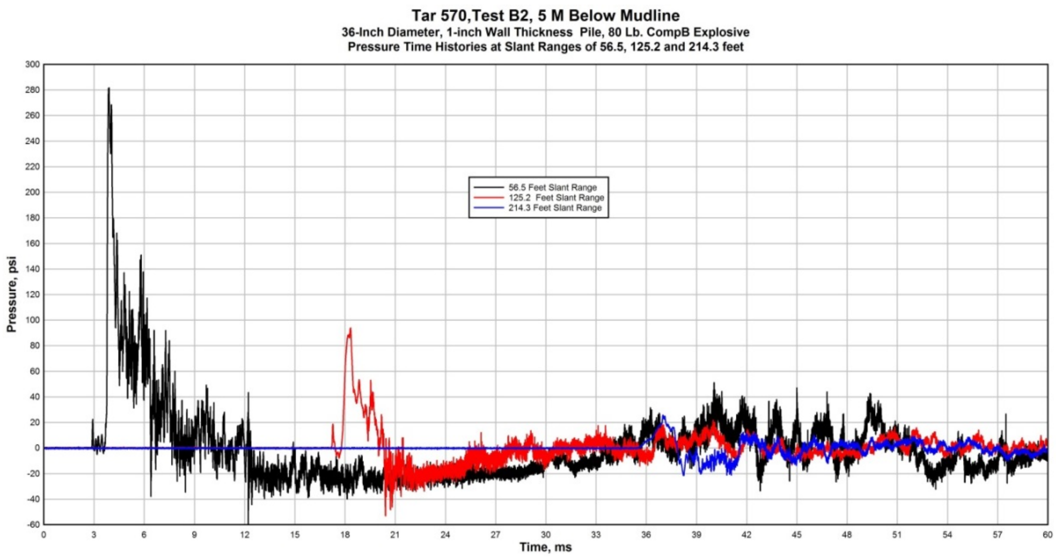

Figure 7 – Time series of three selected shots (personal communication, Dr. P. Dzwilewski, 20 July 2016).

Recall that the criteria themselves are unclear, and the above conclusion is based on this reviewer’s interpretation, which might easily be incorrect. Further, the author of the reviewed report was provided processed data, for which this choice has already been made (personal communication – see Appendix 3). The uncertainty in the suitability of the impulse metric is partly a consequence of the uncertainty in the criteria and partly a consequence of the uncertainty in the processing of the input data described by (Poe et al., 2009).

4.4. Units and their symbols

The report and the calculator use CIP units, but do not follow international standard symbols for these units (IEEE, 2004). Examples of non-standard symbols include ”lbs” (not lb) for pound, “ ’ ” and “ ” ” (not ft and in) for foot and inch, respectively, “psi” or “Psi” (not lbf/in^2) for pound-force per square inch (psi) and “psi-msec” (not lbf/in^2 ms) for psi millisecond.

5. Conclusions

5.1. Limits of validity

The validity limits for input variables are not specified, leading to the potential for error if the model is used outside these limits.

5.2. Presentation

Non-standard use is made of customary inch-pound (CIP) units, requiring the reader to guess the intended meaning. (In most cases the intended meaning is nevertheless clear).

5.3. Metrics and criteria

The definitions of the metrics used are unclear, for both the calculator and the NMFS criteria. For example, the time integration windows for impulse and EFD are not specified. The resulting uncertainty leads to a potential risk of over- or under-estimating impact.

Terminology used is not consistent with the American national standard ANSI S1.1-1994 Acoustical Terminology, nor is it consistent with any international standard this reviewer is aware of.

The terminology used is dated, and no longer used in mainstream scientific literature, making the reports difficult to follow. It would help the reader if definitions were provided of the terms used, preferably making use of a modern terminology standard.

Lack of clarity in the criteria, and specifically the absence of clear definitions of the quantities to be compared with the various thresholds stated in the criteria, leads to the risk of over- or under-estimating the impact region. The resulting uncertainty leads to a potential risk of over- or under-estimating impact.

5.4. Terms of Reference

Table 6 – UWC model implementation

Terms of reference	reviewer reply
1. Assess whether or not the UWC model sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation) for decommissioning activities.	No biological inputs are used by UWC 2 other than the criteria. I am not qualified to judge the criteria. The physical variables are sufficiently considered, the most important ones being charge mass and detonation depth below the mudline.
2. Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure for animals (with an emphasis on sea turtles, but also odontocetes) within the UWC model.	The method is purely empirical so the only assumptions are related to the physical variables chosen as correlates, which are sufficient. See ToR #1.
3. Assess the model validity in relation to field data collected by the PROP program for sea turtles and relevant scientific literature.	Though not available at the time the UWC 2 report was published, one highly relevant publication that should be taken into account for any future work is Soloway & Dahl 2014. I am not familiar with the PROP program. It could be that it was described in one of the reports I did not review.
4. Assess whether or not the UWC meets the Environmental protection Agency's Council for Regulatory Monitoring (CREM) guidelines for model development. 1. UWC Model Implementation • Does the UWC model sufficiently consider all relevant physical variables in estimating acoustic exposure? Specifically, does the model:	See individual replies below.
i. Integrate the new in situ data correctly?	The new in situ data comprise measurements of "Peak Pressure", "Peak Impulse" and "Peak EFD". Empirical correlations are obtained that enable estimation of the variation of these metrics with

	distance from the explosion and charge mass. These correlations are obtained correctly. To the extent I can judge, the measurements are correctly integrated in UWC 2.
ii. Accurately represent the acoustic impact zones from explosive use?	I find it difficult to answer this question. The main reason for this difficulty is the poorly defined terminology, both for the measured quantities “Peak Pressure”, “Peak Impulse” and “Peak EFD” and for the corresponding (unspecified) quantities used in the criteria. My interpretations of the measured quantities and those used in the criteria are provided, respectively, in Table 1 and Table 5, both to the best of my understanding at the time of writing. The quantities listed in these two tables are very similar but not identical. The main differences arise from the treatment of negative (rarefactional) sound pressures. As a general rule, the measured metrics consider only positive (compressional) values of sound pressure, whereas the criteria apply to both positive and negative sound pressure. The neglect of negative sound pressures leads to a risk of underestimating the risk metric, which in turn risks underestimating the impact volume, especially the risk associated with peak impulse. The integration time window for EFD is unspecified. If the chosen window does not include all the energy in the pulse, the EFD would be underestimated.
• Does (or can) the UWC model correctly consider the necessary parameters to estimate effects on sea turtles (and marine mammals) from exposure to explosives based on current scientific knowledge, such as: i. Water, depth, size of target, size of explosives, location of charge (AML/BML)	Water depth is not considered explicitly, but is covered implicitly by use of a different correlation for each scenario. I don’t understand the use of “target” in “size of target”. If it refers to the underwater structure, its size is not an input to UWC 2, nor need it be. The size of the explosives is correctly characterised, in terms of the charge mass (although the quantity is incorrectly referred to as “weight”).

	The location of the charge is characterised in terms of distance below the mudline (BML).
ii. Habitat use and movement of species (e.g. on surface versus in water column)	I am not qualified to comment on habitat use or movement of species.
• How do the UWC model results compare to both field observations and the scientific literature in terms of zones of influence?	The empirical correlations derived to fit the in situ measurements provide a good match (within quantifiable limits that need to be specified) within the range of values considered for water depth, depth BML, charge mass, and distance from explosion. As with any empirical correlation, they should not be used outside the range of parameter values used to determining the correlation.
• Does the UWC model consider the appropriate acoustic exposure metrics? How do the predictive outputs of the UWC model compare with the noise exposure guidelines developed by NMFS?	It is hard to judge this because neither the outputs of UWC 2 nor the quantities involved in the NMFS criteria are clearly specified.
• Comment on the strengths and weaknesses of the UWC modeling approach, and suggest possible improvements (both those that can be accomplished by implementing the current model differently and those that necessitate changes in the model)	The main strength of the correlation method is its robustness when used for interpolating between measurements. The main weakness is its unreliability for extrapolation outside the range of validity of the input parameters values that need to be specified. It can be improved by specifying this range. Specific recommendations are: #1 Specify the limits of validity: maximum and minimum water depth; maximum and minimum depth BML; maximum and minimum charge mass; maximum and minimum distance from explosion. #2 check and clarify definitions of metrics "Peak Pressure", "Peak Impulse" and "Peak EFD" used by UWC 2 (see Table 1) and corresponding criteria

	(Table 5). #3 adopt SI units and ISO standard terminology for scientific work; where it is necessary to convert to units outside the SI, adopt a suitable national (NIST, 2006) or international standard (IEEE, 2004).
• Comment on whether any weaknesses in the UWC model would likely result in over/underestimates of take (and the degree, if possible)	See the text following Table 5 in Sec. 4.3

Table 7 – CREM Guidelines

Terms of reference	reviewer reply
The reviewers shall assess whether or not the UWC model meets the Environmental Protection Agency's CREM guidelines for model evaluation, which are summarized below. Some of the points listed below will have been addressed by the reviewers as part of their comments on Terms of Reference 1 and 2 above. Each reviewer shall ensure that clear answers are provided for the CREM guidelines, though extensive repetition of technical comments is not required. • Have the principles of credible science been addressed during model development?	To my understanding, the cornerstone of credible science is the peer review process, which is what we are carrying out now. It could be that peer review took place during the project, and this is a question for those more directly involved in the project. Perhaps I have misunderstood the question?
• Is the choice of model supported given the quantity and quality of available data?	yes
• How closely does the model simulate the system (e.g., ecosystem and sound field) of interest?	The simulation provides a sufficient (fit for purpose) representation of the measured sound field in within the limits of validity, which need to be specified.
• How well does the model perform?	See my reply to the previous question.
• Is the model capable of being updated with new data as it becomes available?	yes

6. Acknowledgements

I thank Dr A. Scholik-Schlomer, Dr D. Ketten, Dr P. Dahl and Dr P. Dzwilewski for valuable and constructive exchanges.

7. References

Ainslie (2012) Current US National Marin[1]e Fisheries Service criteria for assessing the effects of underwater sound on marine life, TNO memo NO-060-DHW-2012-04396, 7 December 2012.

ANSI (1994) ANSI S1.1-1994 Acoustical Terminology[2]

ANSI (2013) ANSI S1.1-2013 Acoustical Terminology[3]

Cole (1948) Underwater Explosions, Princeton University Press, 1948.

Dzwilewski, Peter T. (2014). ARA Final report – Water Shock Prediction for Explosive removal of Offshore Structures: Underwater Calculator (UWC) Version 2.0 Update based on Field Data

Dzwilewski & Fenton (2003). Shock Wave/Sound Propagation Modeling Results for Calculating Marine Protected Species Impact Zones During Explosive Removal of Offshore Structures, OCS Study, MMS 2003-059.

Finneran, J. J., Schlundt, C. E., Dear, R., Carder, D. A., & Ridgway, S. H. (2002). Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. The Journal of the Acoustical Society of America, 111(6), 2929-2940.

IEEE (2004), IEEE Std 260.1-2004 IEEE Standard Letter Symbols for Units of Measurement (SI Units, Customary Inch-Pound Units, and Certain Other Units), 24 September 2004.

ISO (2016), ISO/DIS 18405.2 Underwater Acoustics – Terminology

Morfey, C. L. (2000). Dictionary of acoustics. Academic press.

NIST (2006) NIST Special Publication 811, 2008 Edition, Guide for the Use of the International System of Units (SI), National Institute of Standards and Technology, Gaithersburg, MD 20899 (Supersedes NIST Special Publication 811, 1995 Edition, April 1995) March 2008

National Oceanic and Atmospheric Administration (NOAA) 2016, Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts, NOAA Technical Memorandum NMFS-OPR-55, July 2016.

[1] The memo NO-060-DHW-2012-04396, written by this reviewer to Mr R.P.A. Dekeling of the Netherlands Ministry of Infrastructure, summarises his understanding of NMFS criteria for assessing the effects of underwater sound on marine life..

[2] ANSI standard current at the time of the work being reviewed

[3] ANSI standard current at the time of the review

Poe et al (2009) Effect of Depth Below Mudline of Charge Placement During Explosive Removal of Offshore Structures (EROS), Final Report, July, 2009, William T. Poe (ESI), Craig F. Adams (Consultant),

Soloway, A. G., & Dahl, P. H. (2014). Peak sound pressure and sound exposure level from underwater explosions in shallow water. The Journal of the Acoustical Society of America, 136(3), EL218-EL223.

USN (2012) USN Atlantic Fleet Training and Testing, draft Environmental Impact Statement/Overseas Environmental Impact Statement, 4 May 2012.

8. Appendix 1: Bibliography of materials provided for review

9. Primary Review Document Titles
1. ARA Final report – Water Shock Prediction for Explosive removal of Offshore Structures: Underwater Calculator (UWC) Version 2.0 Update based on Field Data
2. Underwater Calculator Version 2
3. Effect of Depth Below Mudline of Charge Placement During Explosive Removal of Offshore Structures (EROS)
4. Shock Wave/Sound Propagation Modeling Results for Calculating Marine Protected Species Impact Zones During Explosive Removal of Offshore Structures (OCS Study 2003-059)
5. Pressure Wave and Acoustic Properties Generated by the Explosive Removal of Offshore Structures in the Gulf of Mexico
Secondary Background Document Titles
6. Impacts of the Explosive Removal of Offshore Petroleum Platforms on Sea Turtles and Dolphins
7. Underwater Blast Effects from Explosive Severance of Offshore Platform Legs and Well Conductors
8. Underwater Blast Pressures from a Confined Rock Removal during the Miami Harbor Deepening Project
9. Determination of Acoustic Effects on Marine Mammals and Sea Turtles for the Atlantic Fleet Training and Testing Environmental Impact Statement/Overseas Environmental Impact Statement
10. The Environmental Effects of Underwater Explosions with Methods to Mitigate Impacts
11. NMFS PROP Reports and Necropsy Reports

Document	Document Type	Number of Pages

Document	Document Type	Number of Pages
1. ARA Final report – Water Shock Prediction for Explosive removal of Offshore Structures: Underwater Calculator (UWC) Version 2.0 Update based on Field Data	PDF	35 pp
2. Underwater Calculator Version 2.0	Excel Spreadsheet	1 spreadsheet
3. Effect of Depth Below Mudline of Charge Placement During Explosive Removal of Offshore Structures (EROS)	PDF	71 pp
4. Shock Wave/Sound Propagation Modeling Results for Calculating Marine Protected Species Impact Zones During Explosive Removal of Offshore Structures (OCS Study 2003-059)	PDF	41 pp
5. Pressure Wave and Acoustic Properties Generated by the Explosive Removal of Offshore Structures in the Gulf of Mexico	PDF	72 pp
6. Impacts of the Explosive Removal of Offshore Petroleum Platforms on Sea Turtles and Dolphins	PDF	10 pp
7. Underwater Blast Effects from Explosive Severance of Offshore Platform Legs and Well Conductors	PDF	147 pp
8. Underwater Blast Pressures from a Confinded Rock Removal during the Miami Harbor Deepening Project	PDF	12 pp
9. Determination of Acoustic Effects on Marine Mammals and Sea Turtles for the Atlantic Fleet Training and Testing Environmental Impact Statement/Overseas Environmental Impact Statement	PDF	109 pp
10. The Environmental Effects of Underwater Explosions with Methods to	PDF	54 pp

Document	Document Type	Number of Pages
Mitigate Impacts		
11. NMFS PROP Reports and Necropsy Reports (7 incidents)	Excel Spreadsheets (7), Word (2), and PDF (2)	10 pp + 7 spreadsheets

9. Appendix 2: Statement of Work

Statement of Work
National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review

Underwater Calculator (UWC) version 2.0.

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards. (http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).
Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

The Bureau of Safety and Environmental Enforcement have developed a tool based on a model to predict the effects of underwater explosions used for the removal of oil and gas structures. The modeling tool is called the Underwater Calculator Version 2.0 (UWC). The UWC was developed through a federally-sponsored environmental study to measure sound pressures during explosive use and develop a mathematical model. The development of the UWC was sponsored by the Bureau of Safety and Environmental Enforcement (MMS

Contract 0302P057572) which resulted in the report titled "*Shock Wave/Sound Propagation Modeling Results for Calculating Marine Protected Species Impact Zones During Explosive Removal of Offshore Structures*" (OCS Study 2003-059). The study used field measurements to conduct numerical simulations of various explosive, target, sediment, and marine environments determining the level of energy coupled into the water. In addition, a separate federal-sponsored study calculated the exposures of marine mammals to explosives used for decommissioning in the Gulf of Mexico which are found in the report "*Explosive Removal Scenario Simulation Results – Final Report*" (MMS OCS study 2004-064).

The purpose of the UWC is to conduct assessments of projects using explosives to remove oil and gas structures and to predict the effects and mitigation needs for protected marine species, primarily marine mammals and sea turtles. The UWC needs to be based on sound scientific principals necessary to conduct environmental assessments under federal requirements (e.g., the Endangered Species Act, Marine Mammal Protection Act, and National Environmental Policy Act). The NMFS requires an independent peer review of the UWC to ensure that the data collection methods, analysis, principals of acoustics, and necessary physical and biological factors have been considered to provide a sound scientific model. The Terms of Reference (TORs) are below.

Requirements

NMFS requires three reviewers to conduct an impartial and independent peer review in accordance with the SOW, OMB Guidelines, and TORs below. The reviewers shall have the combined working knowledge and recent experience in the application of underwater acoustics (especially explosives), acoustic modeling, and sea turtle biology.

The underwater acoustician or physicist reviewer(s):

- shall have expertise and working experience with the physics and principals of the modeling of underwater explosives
- shall have relevant experience in the calculation and relationships of peak pressure, impulse, and energy flux density (EFD) as it relates to underwater shock waves caused by explosive use

The mathematical modeling reviewer(s):

- shall have expertise with underwater propagation of acoustic waves and modeling acoustic exposures of animals
- Experience with relevant acoustic modeling efforts dealing with impacts to marine protected species and NMFS acoustic criteria is desirable.

The sea turtle biologist and marine mammal reviewer(s):

- shall have experience with sea turtles (primarily) and marine mammal (secondarily) physiology and the effects of shock wave injury in marine animals

- shall have experience in sea turtle (primarily) and marine mammal (secondarily) habitat usage and behavioral ecology

Tasks for reviewers

- Review the following background materials and reports prior to conducting the review:

Primary Review Document Titles
1. ARA Final report – Water Shock Prediction for Explosive removal of Offshore Structures: Underwater Calculator (UWC) Version 2.0 Update based on Field Data
2. Underwater Calculator Version 2
3. Effect of Depth Below Mudline of Charge Placement During Explosive Removal of Offshore Structures (EROS)
4. Shock Wave/Sound Propagation Modeling Results for Calculating Marine Protected Species Impact Zones During Explosive Removal of Offshore Structures (OCS Study 2003-059)
5. Pressure Wave and Acoustic Properties Generated by the Explosive Removal of Offshore Structures in the Gulf of Mexico
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6. Impacts of the Explosive Removal of Offshore Petroleum Platforms on Sea Turtles and Dolphins
7. Underwater Blast Effects from Explosive Severance of Offshore Platform Legs and Well Conductors
8. Underwater Blast Pressures from a Confined Rock Removal during the Miami Harbor Deepening Project
9. Determination of Acoustic Effects on Marine Mammals and Sea Turtles for the Atlantic Fleet Training and Testing Environmental Impact Statement/Overseas Environmental Impact Statement
10. The Environmental Effects of Underwater Explosions with Methods to Mitigate Impacts
11. NMFS PROP Reports and Necropsy Reports

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2. Underwater Calculator Version 2.0	Excel Spreadsheet	1 spreadsheet
3. Effect of Depth Below Mudline of Charge Placement During Explosive Removal of Offshore Structures (EROS)	PDF	71 pp
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Document	Document Type	Number of Pages
Mitigate Impacts		
11. NMFS PROP Reports and Necropsy Reports (7 incidents)	Excel Spreadsheets (7), Word (2), and PDF (2)	10 pp + 7 spreadsheets

- Participate in two, half-day webinars with NOAA, BSEE, and other personnel to discuss the technical aspects of the UWC, terms of reference, and related questions
- Conduct an independent peer review in accordance with the requirements specified in this SOW, OMB guidelines, and TORs, in adherence with the required formatting and content guidelines

Place of Performance

The place of performance shall be at the contractor's facilities.

Period of Performance

The period of performance shall be from the time of award through August 31, 2016. Each reviewer's duties shall not exceed 12 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

6/10/2016	Contractor selects and confirms reviewers
No later than 6/17/2016	Contractor provides the review documents to the reviewers
6/124 – 9/12/16	Each reviewer conducts an independent peer review as a desk review, including participating in two, half-day seminars
9/12/16	Contractor receives draft reports
9/14/2016	Contractor submits final reports to the Government

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards:

(1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each TOR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

Since this is a desk review travel is neither required nor authorized for this contract. ODCs are not to exceed $500.00.

Restricted or Limited Use of Data

The contractors may be required to sign and adhere to a non-disclosure agreement.

Peer Review Report Requirements

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether or not the science reviewed is the best scientific information available.

2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs.

3. The report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review

   Appendix 2: A copy of this Statement of Work

Terms of Reference for the Peer Review

Underwater Calculator (UWC) version 2.0.

1. Assess whether or not the UWC model sufficiently considers all relevant biological (e.g., animal distribution and movement) and physical variables (e.g., factors affecting sounds propagation) for decommissioning activities.

2. Assess the underlying assumptions resulting from scientific uncertainty in estimating acoustic exposure for animals (with an emphasis on sea turtles, but also odontocetes) within the UWC model.

3. Assess the model validity in relation to field data collected by the PROP program for sea turtles and relevant scientific literature.

4. Assess whether or not the UWC meets the Environmental protection Agency's Council for Regulatory Monitoring (CREM) guidelines for model development.

1. <u>UWC Model Implementation</u>

- Does the UWC model sufficiently consider all relevant physical variables in estimating acoustic exposure? Specifically, does the model:
  i. Integrate the new in situ data correctly?
  ii. Accurately represent the acoustic impact zones from explosive use?
- Does (or can) the UWC model correctly consider the necessary parameters to estimate effects on sea turtles (and marine mammals) from exposure to explosives based on current scientific knowledge, such as:
  i. Water, depth, size of target, size of explosives, location of charge (AML/BML)
  ii. Habitat use and movement of species (e.g. on surface versus in water column)
- How do the UWC model results compare to both field observations and the scientific literature in terms of zones of influence?
- Does the UWC model consider the appropriate acoustic exposure metrics? How do the predictive outputs of the UWC model compare with the noise exposure guidelines developed by NMFS?
- Comment on the strengths and weaknesses of the UWC modeling approach, and suggest possible improvements (both those that can be accomplished by implementing the current model differently and those that necessitate changes in the model)
- Comment on whether any weaknesses in the UWC model would likely result in over/underestimates of take (and the degree, if possible)

2. <u>CREM Guidelines</u>

The reviewers shall assess whether or not the UWC model meets the Environmental Protection Agency's CREM guidelines for model evaluation, which are summarized below.

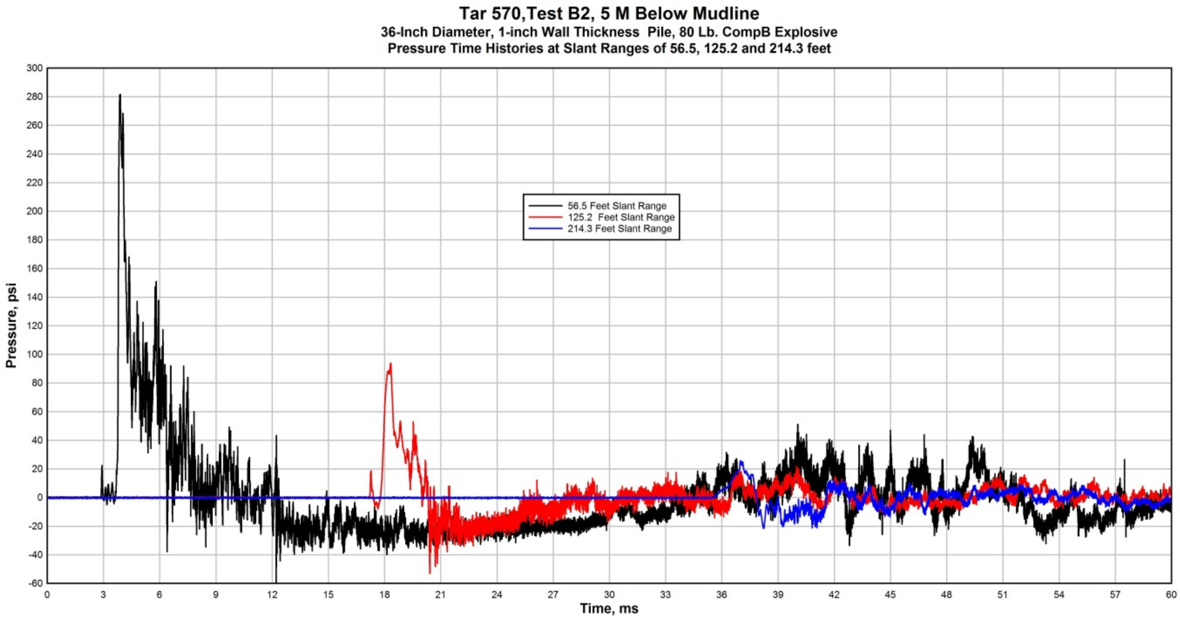
Some of the points listed below will have been addressed by the reviewers as part of their comments on Terms of Reference 1 and 2 above. Each reviewer shall ensure that clear answers are provided for the CREM guidelines, though extensive repetition of technical comments is not required.

- Have the principles of credible science been addressed during model development?
- Is the choice of model supported given the quantity and quality of available data?
- How closely does the model simulate the system (e.g., ecosystem and sound field) of interest?
- How well does the model perform?
- Is the model capable of being updated with new data as it becomes available?

10. Appendix 3: Cited correspondence with Dr. P. Dzwilewski

email 2016-07-20 from P. Dzwilewski to all:

"To give you an idea of the character of the measured pressure time histories from TAR570 (the data used for Underwater Calculator 2), I attached a plot that has three raw records (3 slant ranges). The peak pressures from these plots are 3 of the 10 data points plotted in Figure 3 of my Underwater Calculator 2 report. The specifics of the test are: 36-Inch Diameter, 1-inch Wall Thickness Pile, 80 Lb. CompB Explosive, 5 m below mudline.
We still need to find out how the authors of the report calculated the impulse and EFD values that they reported. Jonathan volunteered to track this down for us. I could try some things but I decided against this approach as I would only be guessing."



email 2016-07-22 from P. Dzwilewski to P. Dahl (cc all):
“I did not do much with the pressure time histories. I just used the tabulated peaks. There was no time to study the data. This was a very small project: I plotted the data, did the analysis, developed the Underwater Calculator, and wrote the final report in 60 hours.
As I remember, I only plotted data from the 2008 file. At the top of the file, there is a recording interval time given, labeled HResolution, with a value of 2e-6 seconds.
Hoffest is probably a misspelling, could be Hoffset, I believe. I do not know what that means. Could be a pretrigger time and may have been used to define the time zero for the detonation event.
I think that you are correct in your interpretation of "A_R25D10", which is the gauge designation.
I never looked at the 2003 file, so not sure how "time" was handled.
The spreadsheet I emailed earlier today gives explosive weight, detonation location below the mudline, and slant ranges for the various gauges for each test for the 2007 and 2008 tests.”